NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

OPTIMIZING THE DISTRIBUTION OF UNITED STATES ARMY OFFICERS

by

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September 2005

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REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.			
1. AGENCY USE ONLY *(Leave blank)*	**2. REPORT DATE** September 2005	**3. REPORT TYPE AND DATES COVERED** Master's Thesis	
4. TITLE AND SUBTITLE: Optimizing the Distribution of U. S. Army Officers			**5. FUNDING NUMBERS**
6. AUTHOR(S) McElroy, Jeremy S.			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000			**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A			**10. SPONSORING/MONITORING AGENCY REPORT NUMBER**
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.			
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.			**12b. DISTRIBUTION CODE**

13. ABSTRACT

The U.S. Army distributes its 51,000 competitive category officers among manning targets specified by location, rank and skill that change over time in response to changing requirements. The officer inventory also changes over time and does not exactly match the manning target requirements. The Army responds to imbalances by redistributing officers in order to provide each location with the minimum required officers while minimizing the number of unfilled targets and excess officers at each location. This thesis focuses on branch officers, branch targets and generalist targets with ranks from Branch Qualified Captain to Colonel. Using data provided by the Army, we formulate an integer programming model called DISTRIBUTOR. When DISTRIBUTOR allows all officers in the inventory to move, it finds only 340 unfilled targets but this requires 4,688 or 28% of the inventory to move. We reduce the number of moves by using DISTRIBUTOR in two sequential steps. The first step optimally distributes officers at each location and identifies the excess officers and unfilled targets at each location. The second step takes the excess officers and distributes them to unfilled targets at other locations. The two-step leaves only 346 targets unfilled (6 more) but requires only 1,373 or 8% of the inventory to move. By allowing rank substitution DISTRIBUTOR can reduce the unfilled targets to 70.

14. SUBJECT TERMS Optimization, Integer Programming, Manpower, Officer Distribution, U. S. Army Human Resource Command			**15. NUMBER OF PAGES** 47
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	**18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified	**19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified	**20. LIMITATION OF ABSTRACT** UL

NSN 7540-01-280-5500 Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

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OPTIMIZING THE DISTRIBUTION OF UNITED STATES ARMY OFFICERS

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
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ABSTRACT

The U.S. Army distributes its 51,000 competitive category officers among manning targets specified by location, rank and skill that change over time in response to changing requirements. The officer inventory also changes over time and does not exactly match the manning target requirements. The Army responds to imbalances by redistributing officers in order to provide each location with the minimum required officers while minimizing the number of unfilled targets and excess officers at each location. This thesis focuses on branch officers, branch targets and generalist targets with ranks from Branch Qualified Captain to Colonel. Using data provided by the Army, we formulate an integer programming model called DISTRIBUTOR. When DISTRIBUTOR allows all officers in the inventory to move, it finds only 340 unfilled targets but this requires 4,688 or 28% of the inventory to move. We reduce the number of moves by using DISTRIBUTOR in two sequential steps. The first step optimally distributes officers at each location and identifies the excess officers and unfilled targets at each location. The second step takes the excess officers and distributes them to unfilled targets at other locations. The two-step leaves only 346 targets unfilled (6 more) but requires only 1,373 or 8% of the inventory to move. By allowing rank substitution DISTRIBUTOR can reduce the unfilled targets to 70.

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ACKNOWLEDGMENTS

I would like to express my gratitude to Professor Robert Dell for his patience and guidance. My thesis experience was very enriching thanks to him. I would also like to thank LTC Alejandro Hernandez for his assistance and enthusiasm. I thank the members of the Officer Distribution Branch at the U. S. Army Human Resource Command. I thank MAJ Jim Dzwonchyk for presenting this problem and providing his valuable insight. I thank the members of the Distribution Development and Programs Branch at the U. S. Army Human Resource command. I especially want to thank MAJ Jeff House for all the assistance he provided.

I thank Doctors Boris and Svetlana Keyser for their healing, counsel, and friendship. Finally, I thank my wife, Maria, and sons, Alexander and Nicholas for their patience and support during this effort.

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EXECUTIVE SUMMARY

The U.S. Army distributes its 51,000 competitive category officers among manning targets specified by location, rank and skill. The officer inventory does not exactly match the manning target requirements. Both the inventory and the requirements change over time. The Army responds to imbalances by redistributing officers in order to provide each location with the minimum required officers while minimizing the number of unfilled targets and excess officers at each location.

This thesis focuses on branch officers, branch targets and generalist targets for ranks that range from Branch Qualified Captains to Colonel. For data provided by the Army in December 2004 this consists of 16,960 officers and 16,324 targets. The current distribution of these officers among the targets has 2,167 unfilled targets and 2,803 excess officers. There is an overall shortfall of 340 majors.

A branch target requires an officer from a specific branch such as infantry or artillery, whereas generalist targets can be more easily filled. The different generalist categories include branch immaterial, combat arms, infantry and armor, and logistics. Some skills are more capable of filling generalist targets than other skills due to the number of officers in the inventory.

We evaluate distributions based on the number of unfilled targets, number of moves required, and percentage of officers from each branch filling generalist targets. A target that does not receive an exact rank and skill match is considered unfilled. Moves are the actual change in inventory of officers by their branch control skill at each location.

The Army currently uses a linear programming model MANGRUNTS to distribute its officers. Locations are designated as donors or receivers based on number of officers compared to the targets for each assigned skill and rank. Locations donate officers above the target and receive officers weighted by the priority of the location.

Using the data provided by the Army, we formulate an integer programming model called DISTRIBUTOR. When DISTRIBUTOR allows all officers in the inventory to move, it finds only 340 unfilled targets but this requires 4,688 or 28% of the inventory to move.

We reduce the number of moves by using DISTRIBUTOR in two sequential steps. The first step optimally distributes officers at each location and identifies the excess officers and unfilled targets at each location. The second step takes the excess officers and distributes them to unfilled targets at other locations.

The first step in the two-step run filled 619 targets without requiring any moves between locations. The second step leaves only 346 targets unfilled (6 more) but requires only 1,373 or 8 % of the inventory to move.

We include additional constraints requiring rank substitution for the two-step model when possible. These constraints assign an excess officer, one rank above or below, with the correct skill to any location with an unfilled target. These changes give a better overall solution leaving only 70 targets without an officer with the required skill and grade or a rank substitute. This distribution required a total of 1,405 (only 32 more moves).

We add another set of constraints to improve the fair share of generalist targets. We set fair share targets for the number of generalist billets that a branch should fill based on its officer inventory and branch targets. Without these constraints, the total deviation over or under the fair share targets is 515 officers. With these constraints, this reduces to 368 while still leaving only 70 targets without a required officer or rank substitute and requiring only 1,414 moves. Distributor can significantly reduce the number of moves required to effectively distribute the officer inventory.

I. DISTRIBUTION OF UNITED STATES ARMY OFFICERS

Yearly, the United States Army Human Resource Command (HRC) orders about 40% of its 51,000 officers to move among its authorized billets [HRC 2005]. These moves are required by officer career development or redistribution. A redistribution responds to imbalances between the officer inventory and the Army manning targets specified by grade, skill and location. Today, requirements are changing as the Army transforms its officer corps into a modular, expeditionary and more lethal force [HRC 2005] while fighting the Global War on Terror. The challenge is distributing a fluctuating officer inventory among changing requirements while satisfying competing demands. This thesis addresses the problem of optimally distributing officers throughout the Army using an integer program called DISTRIBUTOR. DISTRIBUTOR improves the Army HRC's ability to develop a distribution plan that meets its competing demands.

A. THESIS ORGANIZATION

The remainder of this chapter describes the current distribution, distribution imbalances and the contribution of this thesis. Chapter II reviews related Operations Research literature. Chapter III presents the DISTRIBUTOR formulation. Chapter IV describes model implementation and results. Chapter V presents conclusions.

B. CURRENT OFFICER DISTRIBUTION

1. Authorizations and Manning Targets

Congress authorizes the number of Army officers. The current inventory of officers does not meet the authorization requirements due to rank and assigned skill imbalances [Dzwonchyk 2004a]. The Army G1 issues manning guidance that prioritizes unit manning levels, and HRC creates manning targets which bridge the gap between authorizations and inventory [House 2005]. Requirements for locations change as the manning priority of the location changes or in response to a change in unit structure. As a unit prepares to deploy, its manning priority is increased to ensure it has the required numbers and types of officers for its mission. Other units may have their manning priority reduced to compensate if necessary.

2. Control Skill

The Army categorizes its officers by their branch control skill. For example, an officer with a branch control skill 11 is an infantry officer. Table 1 lists the 16 branch control skills for competitive category officers. Special branches such as medical and chaplains are not competitive category officers.

Branch Control Skill	Description
11	Infantry
13	Artillery
14	Air Defense
15	Aviation
18	Special Forces
19	Armor
21	Combat Engineer
25	Signal Corps
31	Military Police
35	Military Intelligence
42	Adjutant General
44	Finance
74	Chemical
88	Transportation
91	Ordnance
92	Quartermaster

Table 1. Branch control skills. Branch control skills and their descriptions.

3. Assigned Skill

An officer's assigned skill is what the Army assigns that officer to do at a location. Branch officers fill 84 assigned skills but not all branch officers are eligible for all assigned skills. For example, an infantry officer may be assigned to a target with an infantry assigned skill, but an armor officer would not be assigned to such a target.

4. Generalist Skills

There are four generalist skills, also known as branch immaterial skills that can be filled by officers from a variety of qualified branches. For example, any branch officer can fill a 01A generalist target. There are other generalist targets that can be filled by a subset of branch officers. For example, only officers with branch control skills 88, 91 or 92 may fill a 90A generalist target.

5. Current Distribution Model

The Army currently uses MANGRUNTS (Manning to Grade Unit Target Skill) [Dzwonchyk 2004a]. MANGRUNTS is generated using the Generic Algebraic Modeling System (GAMS) [GAMS 2005] and solved using Cplex [GAMS 2005]. MANGRUNTS' input derives from a comparison of officer inventory and targets by assigned skill at each location. An imbalance of officers and targets designates a location as either a donor or receiver for an assigned skill and rank. MANGRUNTS uses donors to minimize unfilled targets. MANGRUNTS seeks to fill locations to the manning priority level set by the manning guidance.

C. DISTRIBUTION IMBALANCES

1. Skill Imbalances

The current inventory of a branch is the number of all officers with the control skill for that branch. A branch with more officers than the number of branch specific targets has officers available to fill generalist targets.

Table 2 displays the number of combat arms officers in the inventory compared with the number of branch specific targets. The Army distributes these officers to branch assignments, generalist 01A assignments and combat arms generalist 02A assignments. Infantry and armor officers may also be assigned to 03A assignments. Table 2 shows 972 of the 1,183 engineer officers and 653 of the 825 special forces officers, each about 80%, are required to fill their branch targets while the other branches require about 60% of their officer inventory to fill their branch targets.

Branch Skill	Inventory	Branch Targets	Available for Gen
Infantry	2058	1240	818
Artillery	1471	962	509
Air Defense	679	400	279
Aviation	1645	950	695
Special Forces	825	653	172
Armor	1188	684	504
Engineer	1183	972	211

Table 2. Combat arms branch skills. Combat arms branch skills inventory, targets and inventory available for distribution to generalist targets.

2. Rank Imbalances

The current inventory of a branch may be sufficient but the inventory at a particular rank may not be. Table 3 displays the inventory and targets by rank. The current inventory of majors is 340 less than the number of major targets.

Rank	Inventory	Targets	Excess	Shortage
COL	1802	1677	125	0
LTC	4401	4300	101	0
MAJ	6078	6418	0	340
BQCPT	4679	3920	759	0

Table 3. Rank Imbalances. Total inventory, targets, excess officers and officer shortages.

3. Assignments of Officers at Units

Each individual location assigns its officers to targets. This assignment may not be optimal in filling as many targets as possible due to the fill of generalist targets. For example, a location may have an excessive number of infantry officers assigned to infantry targets while it has unfilled generalist targets. That location could fill its targets by assigning its excess infantry officers to the generalist targets.

4. Seasonality

Service schools, overseas rotations, and unit deployments make some officers unavailable for distribution in some distribution cycles.

D. THESIS CONTRIBUTION

This thesis uses an integer program named DISTRIBUTOR to do a global distribution and a two-step distribution. The global distribution allows every officer to move to fill targets and serves as a benchmark or reference point for the best possible solution in filling targets.

We reduce the number of moves by using DISTRIBUTOR in sequential steps. The first step optimally distributes officers at each location and identifies the excess officers and unfilled targets at each location (this step is overlooked in MANGRUNTS). A location is a major unit, usually a brigade. The second step takes the excess officers and distributes them to unfilled targets at other locations.

An example that motivates the two-step process is illustrated in the following tables. A location has five targets for Majors and a current inventory as listed in Table 4. Table 4 shows the location has five infantry Majors filling three targets. The location currently has an unfilled 02A target and an unfilled 03A target.

Major	Infantry	02A	03A	Total
Targets	3	1	1	5
Infantry	5	0	0	5

Table 4. Example location's current distribution. Example location's targets and inventory. There are three infantry targets, one combat arms generalist (02A) target and one infantry or armor generalist (03A) target. The 02A and 03A targets are currently not filled and there are two excess infantry officers.

In the first step of the two-step process, DISTRIBUTOR takes the current inventory and optimally distributes it at each location. For this example, the two excess infantry officers fill the unfilled 02A and 03A generalist targets (Table 5).

Major	Infantry	02A	03A	Total
Targets	3	1	1	5
Infantry	3	1	1	5

Table 5. DISTRIBUTOR's Step 1 distribution for the example location. Three infantry Majors remain assigned to infantry while one is assigned to 02A and the other to 03A.

In contrast, MANGRUNTS leaves five infantry officers assigned to the three infantry targets. The location receives an additional artillery officer and an additional infantry officer to fill the open targets. This distribution is acceptable but requires two officers to unnecessarily move to the location. Unnecessary moves result in additional Permanent Change of Station (PCS) costs and Army families relocating.

Major	Infantry	02A	03A	Total
Targets	3	1	1	5
Infantry	5	0	1	6
Artillery	0	1	0	1

Table 6. MANGRUNTS distribution for example location. There are five infantry officers assigned to three infantry targets. One artillery officer is received and distributed to the 02A target. An additional infantry officer is received and distributed to the 03A target.

We compare distributions by how well they meet manning guidance, fill targets, minimize moves, and fair share generalist targets. The manning priority level of each location determines the aggregate fill percentage for that location. Manning Priority One locations are filled to minimum of 98% while Manning Priority Three locations are filled to a minimum of 85%. Each distribution is evaluated on the number of excess officers and the number of unfilled targets at each location. The number of officers received or donated indicates the number of moves required for a location by the distribution. Each branch has a fair share target representing the number of officers from that branch that

should fill generalist targets. The number of officers over or under fair share targets indicates if the distribution fairly assigns the generalist targets among the branches.

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II. RELATED RESEARCH

All United States military services face similar challenges in distributing their inventory of officers. This chapter reviews current officer distribution practice and other large scale military assignment.

The Army's officer resource allocation problem exists at two levels. The higher level is the aggregate number of officers distributed to a location. The next level is the assignment of an individual officer to a target by a local commander. This thesis focuses on the aggregate number of officers distributed to a location.

A. U.S. NAVY, AIR FORCE, MARINE CORPS OFFICER DISTRIBUTION

The United States Navy and the United States Air Force appear to have a stable distribution of officers at the major command level. The focus of these services is on the next level of distribution, the assignment of the individual officer to a specific billet.

The Navy appears to manage the distribution of its officers without models by allowing each warfare specialty to distribute its officers. For example the Surface Warfare community assigns officers to billets throughout the year focusing on the officer's career progression and ensuring a good fit of the individual officer's skills with the billet the officer is assigned to [Hatch 2005].

The Air Force is similar to the Navy in handling its officer distribution. The officers are divided by warfare specialty and weapons platform. Each officer has a Transitional Officer Development Program (T-ODP) which describes his career desires. Three times a year the Air Force Personnel Center makes a Vulnerable Mover List (VML). This list tells each major command which officers are eligible to move. A Development Team (DT), composed of senior officers, makes a recommendation for assignment based on the officer's career and his T-ODP. This recommendation is used to find the best match for the officer [Air Force Personnel Command 2005].

The Marine Corps has 18,000 officers in its inventory. Each year 33% of this inventory moves. All officers with three years on station are eligible. The Marine Corps uses the Officer Staffing Goal Model (OSGM) to help guide how the inventory of officers is distributed. Decision Support Associates Incorporated developed OSGM and

provides support. This model takes the inventory of officers projected to move and distributes these officers to an appropriate billet at another command. The model assigns officers with approved future locations to an appropriate billet at their future location. OSGM distributes officers not eligible to move to an appropriate billet at their current command. Any officer eligible to move that OSGM does not distribute remains with their current command [Lianez 2005].

B. LARGE SCALE MILITARY MANPOWER ASSIGNMENT MODELS

The Marine Corps faces a problem with mobilizing officers in a time of crisis. Bausch et al. [1991] develop a network model that is both a distribution model and an assignment model. It is an extension of the transportation model which aggregates officers by rank and skill. These groups of officers with the same rank and skill serve as the supply nodes. Demand nodes are also aggregated by qualifications and location. The arcs exist between supply nodes and demands nodes they are eligible to fill. The arc costs represent transportation costs. The three objectives of the model are to maximize fill, maximize fit and minimize turbulence. Bausch et al. [1991] also report on the model's use. Like the modeling by Bausch et al., DISTRIBUTOR aggregates officers and targets and its use in sequential steps is a way to minimize the turbulence of an Army officer distribution.

Sweeney [1993] presents an elastic network model named Officer Staffing Goal Model-Naval Postgraduate School (OSGM-NPS) which addresses the same problem as the OSGM model. This model takes the available officers and allocates them to the requirements they are eligible to fill. The requirements are divided into five priority classes. The model seeks to fill the maximum number of requirements while fair sharing unmet requirements among each priority class. Each requirement is filled with a best fit officer but never at the expense of the overall fill. His model, OSGM-NPS out performed the version of OSGM used at the time.

Tivnan [1998] describes measures of effectiveness and implements rank substitutions. In his thesis, Tivnan [1998] presents a prototype elastic network model named Enlisted Assignment Model-Global. This model assigns individuals to targets while balancing unfilled targets, making rank and skill substitutions, and minimizing permanent change of station costs. Tivnan presents four measures of effectiveness which

are fill percentage by geographic location, number of transcontinental transfers, percentage of perfectly matched assignments and number of Marines available but not assigned. We add constraints to DISTRIBUTOR requiring rank substitution and use similar measures of effectiveness to evaluate distributions.

Shrimpton and Newman [2005] provide a description of branch and functional control skills. They also give insight into the career progression of Army officers. They develop a network model to optimize the designation of Army officers into career fields. Each year the Army designates officers at their 10 year mark to either stay in a branch skill or transition to a functional area skill. The scale of this problem is around 1,500 officers from the 16 branches which may remain in their branch or transition to one of the 17 functional areas. Each officer submits a prioritized list of the branch or functional area the officer desires to fill. A panel of senior officers reviews each officer's qualifications and his prioritized designation list and ranks the officer for the eligible branch and functional areas. The panel's recommendations and the officer's preference are used to develop an arc cost for each officer to branch or functional area pairing. The model was able to find feasible solutions when a panel of officers was unable to. The low number of appeals from officers regarding the results of the designation process speaks of the success rate. The Army started using the model in 1999 and it is a vital piece of the Army's Career Field Designation Process [Shrimpton and Newman 2005].

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III. FORMULATION

This chapter presents the mathematical formulation of DISTRIBUTOR.

A. OBJECTIVE FUNCTION

DISTRIBUTOR's objective function is a piecewise linear function to encourage shortages to spread among locations. The function seeks to minimize the number of excess officers or unfilled targets at each location. The penalty per officer over or under increases as the shortage or excess at a location increases. The penalty has intervals, each with an upper-bound. Figure 1 presents a conceptual picture of how total penalty increases as the number of officers deviates from a target.

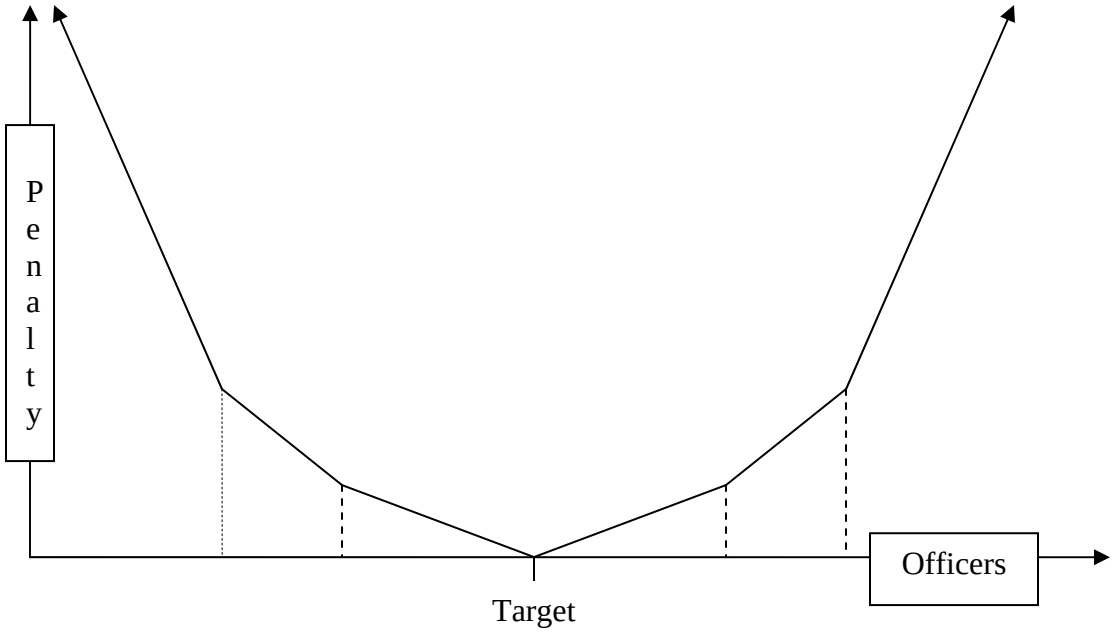

Figure 1. Visual display of DISTRIBUTOR's objective function. The penalty per unit deviation increases as the number of officers increases from the target number.

B. MODEL SUMMARY

DISTRIBUTOR, as the name implies, distributes a set of officers among a set of targets. It fills each target with an eligible officer or determines the target is unfilled. At the same time, it distributes each officer to a target or determines the officer is excess. The objective function minimizes elastic variables representing unfilled targets and the

excess officers. Constraints require a minimum number of targets are filled at each location according to the manning level guidance.

Indices [approximate cardinality]

l	Location (e.g. 3IDH31, 101101,10M11M,…) [309]
a	Assigned skill [81]
c	Branch control skill [16]
r	Military rank [4]
i	Interval for (piecewise line) objective function[4]
m	Manning priority level [3]

Sets

$ELIG_a$	set of branch control skills that fill assigned skill a
$ASGN_c$	set of assigned skills that are filled by branch control skill c
MP_m	set of l that has manning priority m

Parameters [units]

$inventory_{l,a,c,r}$	Number of officers at location l, assigned to assigned skill a, with control skill c and rank r [officers]
$target_{l,a,r}$	Targets at location l for assigned skill a, with rank r [officers]
$penalty_{a,i}$	Penalty at assigned skill a and interval i [units]
$bound_i$	Upper bound at interval i [officers]
$manning_m$	Manning percentage for manning priority level m [officers]

Decision Variables [units]

$ASSIGNED_{l,a,c,r}$	Officer distributed to location l, assigned skill a, possessing a control skill c, and rank r [officers]
$UNDER_{l,a,r,i}$	A shortfall at location l, for an officer assigned skill a, rank r, and interval i [officers]
$OVER_{l,c,r,i}$	Excess officers at location l with control skill c, rank r and interval i [officers]

Constraints and objective function

$$MIN \sum_{l,a,r,i} UNDER_{l,a,r,i}\, penalty_{a,i} + \sum_{l,c,r,i} OVER_{l,c,r,i}\, penalty_{a,i}$$

Subject to:

$$\sum_{c \in ELIG_a} ASSIGNED_{l,a,c,r} + \sum_{i} UNDER_{l,a,r,i} = target_{l,a,r} \quad \forall l,a,r. \tag{1}$$

$$\sum_{l,a \in ASGN_c} ASSIGNED_{l,a,c,r} + \sum_{l,i} OVER_{l,c,r,i} = \sum_{l,a \in ASGN_c} inventory_{l,a,c,r} \quad \forall c,r. \tag{2}$$

$$\sum_{a,c,r} ASSIGNED_{l,a,c,r} \geq manning_m \sum_{a,r} target_{l,a,r} \quad \forall m, l \in MP_m. \tag{3}$$

$$0 \leq UNDER_{l,a,r,i} \leq bound_i \text{ and integer } \forall l,a,r,i. \tag{4}$$

$$0 \leq OVER_{l,c,r,i} \leq bound_i \text{ and integer } \forall l,c,r,i. \tag{5}$$

$$0 \leq ASSIGNED_{l,a,c,r} \text{ and integer } \forall l,a,c,r. \tag{6}$$

Constraint set (1) ensures each target is filled with an officer or an under variable. Constraint set (2) ensures every officer is assigned to a target or to an over variable. Constraint set (3) ensures each location is filled to the minimum for its manning priority level. Constraint set (4) restricts the number of shortages at each location, assigned skill, rank and interval. Constraint set (5) restricts the number of excess officers at each location, control skill, rank and interval. Constraint sets (4) and (5) also stipulate non-negativity and integer as does constraint set (6).

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IV. IMPLEMENTATION AND RESULTS

This chapter presents the data, distributions and comparisons with the current distribution.

A. OVERVIEW

1. Current Distribution

HRC provided an officer inventory file with 41,934 officers [Dzwonchyk 2004b] that includes Lieutenants, Non-Branch Qualified Captains and functional area officers. Typically, a Lieutenant comes from a school to a location and leaves his or her location by either transferring to an advanced school or leaving the Army. A Non-Branch Qualified Captain comes from an advanced school to a location where he or she becomes a Branch Qualified Captain. At the 10 year mark of their career, the Army designates each officer to continue serving in their branch or to serve in a functional area. The Army has 17 functional areas which include Army acquisition corps, information systems engineering, strategic intelligence, foreign area officer, operations research/systems analysis. These functional area officers (5,174 in the data provided) fill only functional area targets, not generalist targets. For this reason, this thesis focuses on branch officers, branch targets and generalist targets with ranks Branch Qualified Captain to Colonel.

The data set consisting of Branch Qualified Captains to Colonel contains 16,324 targets and an inventory of 16,960 officers. The current distribution of officers among the targets has 2,167 unfilled targets and 2,803 excess officers. This chapter presents the implementation of the global and two-step distribution models and the results of each.

2. Data

The model has two input data files received 5 December, 2004 [Dzwonchyk 2004b]. The current inventory file and target file. The current inventory file lists all the officers by location, assigned skill, control skill, and rank. The target file lists all the targets by location, assigned skill, and rank.

In Chapter 1, Table 3 displays the total number of officers in the inventory for each rank. Comparing this with the total number of targets shows there is a shortage of 340 majors so the best distribution will have at least 340 unfilled targets.

3. Xpress

DISTRIBUTOR is implemented in Xpress-MP, optimization software by Dash Optimization [Xpress 2005]. The model generates and solves in less than 10 seconds. The problem size is about 7,400 constraints, 47,000 integer variables and 104,000 non-zero entities.

4. Measures of effectiveness

This thesis evaluates each distribution by comparing it with the current distribution of officers at the locations. The four measures are fill percentage, unfilled targets, number of moves and spread of generalist targets.

a. Fill Percentage

The fill percentage is the number of officers assigned to a location divided by the number of targets for that location. Each location has a manning priority level that specifies the minimum percentage of officers required at the location. Manning Priority One locations are filled to minimum of 98% while Manning Priority Three locations are filled to a minimum of 85%.

b. Unfilled Targets

This is the number of targets at a location not filled by an officer with the required skill and rank. The current distribution has 2,167 unfilled targets.

c. Number of Moves

A move occurs when the officer inventory by control skill changes at a location. When an officer is distributed to a different location, the location's number of officers with that rank and skill increases by one. The number of officers with that rank and skill goes down at the location the officer came from. The following formula is used to compute the number of required moves for location *l* for officers with skill *a* and rank *r*.

$$move_{l,c,r} = (|\sum_{a} inventory_{l,a,c,r} - (\sum_{a} ASSIGNED_{l,a,c,r} + \sum_{i} OVER_{l,c,r,i})|)/2 \quad \forall l, c, r$$

d. Generalist Skills

Another measure of effectiveness for a distribution is the number of officers distributed to branch assignments and to generalist assignments. Table 7

displays the current assignments for each branch skill. For example, 72.16% of branch 11 officers are assigned to infantry targets and 9.96% are assigned to a generalist 01A target. The percentages in bold and italics indicate assignments of officers without the required control skill for that generalist target. There are 106 officers assigned to either 02A or 90A targets that do not come from qualifying branches.

Officer	Branch	01A	02A	03A	90A
11	72.16%	9.96%	17.54%	0.24%	***0.10%***
13	72.06%	10.88%	16.93%	0.00%	***0.14%***
14	70.54%	11.93%	17.38%	0.00%	***0.15%***
15	72.71%	10.64%	15.08%	0.00%	***1.58%***
18	85.58%	5.94%	8.12%	0.00%	***0.36%***
19	69.28%	13.05%	17.00%	0.17%	***0.51%***
21	81.57%	11.58%	6.59%	0.00%	***0.25%***
25	85.21%	13.87%	***0.76%***	0.00%	***0.15%***
31	82.50%	16.03%	***1.47%***	0.00%	0.00%
35	89.59%	9.56%	***0.49%***	0.00%	***0.35%***
42	85.27%	14.06%	***0.67%***	0.00%	0.00%
44	86.64%	13.36%	0.00%	0.00%	0.00%
74	78.20%	19.91%	***0.95%***	0.00%	***0.95%***
88	59.90%	11.93%	***0.62%***	0.00%	27.55%
91	42.79%	14.33%	***0.65%***	0.00%	42.23%
92	41.64%	12.75%	***0.25%***	0.00%	45.36%

Table 7. Current assignment of officers among branch and generalist targets. The numbers in bold and italics are officers assigned to targets they are not eligible to fill. For example, 0.95% of the branch 74, chemical branch, is currently distributed to a generalist combat arms target.

Branches fill generalist targets based on their fair share. This fair share is the number of generalist targets times the available branch inventory divided by the total inventory available from all the eligible branches. In establishing fair share targets a preference is made as to which generalist skills are allocated first. For example infantry, branch 11, inventory is used to fill infantry branch targets. The remaining infantry inventory then fills 03A generalist targets, followed by the 02A combat arms generalist targets and finally the 01A generalist targets. The number of 03A targets to be filled by the infantry branch is determined as follows. Only infantry or armor officers can fill the 25 generalist 03A targets. After filling their branch targets, there are 393 infantry and 277 armor officers remaining for a total eligible population of 670 (393+277). The

infantry fair share of the 25 generalist 03A targets is 25 times 393 divided by 670 or about 15. Dividing 15 by the infantry branch inventory total of 2,058 is 0.73%.

Table 8 displays the fair share of each branch by assigned skill. For example branch 15, aviation branch, should distribute 64.62% of its officers to branch 15, 14.35% to fill 01A generalist, and 21.03% to fill 02A combat arms generalist targets. Referring back to Table 7, the current distribution has 72.71% of branch 15 officers filling branch 15 targets, 10.64% filling 01A targets and 15.08% filling 02A targets.

Officer	Branch	01A	02A	03A	90A
11	66.96%	13.27%	19.05%	0.73%	0.00%
13	71.04%	11.83%	17.13%	0.00%	0.00%
14	68.92%	13.25%	17.82%	0.00%	0.00%
15	64.62%	14.35%	21.03%	0.00%	0.00%
18	81.09%	7.15%	11.76%	0.00%	0.00%
19	64.31%	14.06%	20.79%	0.84%	0.00%
21	85.29%	6.00%	8.71%	0.00%	0.00%
25	84.91%	15.09%	0.00%	0.00%	0.00%
31	84.56%	15.44%	0.00%	0.00%	0.00%
35	89.45%	10.55%	0.00%	0.00%	0.00%
42	85.81%	14.19%	0.00%	0.00%	0.00%
44	76.72%	23.28%	0.00%	0.00%	0.00%
74	81.52%	18.48%	0.00%	0.00%	0.00%
88	61.38%	7.13%	0.00%	0.00%	31.49%
91	44.65%	9.86%	0.00%	0.00%	45.49%
92	42.96%	10.02%	0.00%	0.00%	47.02%

Table 8. Fair share assignment of officers among branch and generalist targets.

B. GLOBAL DISTRIBUTION

DISTRIBUTOR allows all officers to change locations while seeking to minimize the number of excess officers and unfilled targets. DISTRIBUTOR results fill all locations according to manning level guidance and fill all but 340 targets. This is the best possible distribution in filling targets due to the shortage of Majors. This distribution requires 4,688 or 28% of the officer inventory to move. Table 9 presents the spread of each branch among assigned skills. The distribution ensures officers are assigned only to qualified targets.

Officer	CSK	01A	02A	03A	90A
11	62.97%	27.45%	9.14%	0.44%	0.00%
13	70.22%	11.08%	18.69%	0.00%	0.00%
14	68.92%	13.11%	17.97%	0.00%	0.00%
15	64.98%	9.85%	25.17%	0.00%	0.00%
18	82.79%	11.15%	6.06%	0.00%	0.00%
19	63.97%	11.78%	22.98%	1.26%	0.00%
21	86.39%	1.18%	12.43%	0.00%	0.00%
25	83.84%	16.16%	0.00%	0.00%	0.00%
31	82.50%	17.50%	0.00%	0.00%	0.00%
35	89.73%	10.27%	0.00%	0.00%	0.00%
42	87.55%	12.45%	0.00%	0.00%	0.00%
44	82.76%	17.24%	0.00%	0.00%	0.00%
74	82.70%	17.30%	0.00%	0.00%	0.00%
88	61.99%	9.96%	0.00%	0.00%	28.04%
91	48.37%	3.81%	0.00%	0.00%	47.81%
92	44.12%	19.29%	0.00%	0.00%	36.59%

Table 9. DISTRIBUTOR's assignment of officers among branch and generalist targets. There are no ineligible officers assigned to generalist billets.

C. TWO-STEP DISTRIBUTION

We reduce the number of moves by using DISTRIBUTOR in two sequential steps. The first step optimally distributes the officers currently at each location among that location's targets. We modify DISTRIBUTOR by substituting the following equation for constraint (2).

$$\sum_{a \in ASGN_c} ASSIGNED_{l,a,c,r} + \sum_{i} OVER_{l,c,r,i} = \sum_{a \in ASGN_c} inventory_{l,a,c,r} \quad \forall l, c, r.$$

This constraint ensures every officer at location *l* is assigned to an eligible target at location *l* or is excess at location *l*. The first step reduces the number of unfilled targets by 619 without moving any officers between locations.

The second step uses the original DISTRIBUTOR formulation and assigns the excess officers to unfilled targets at other locations. This distribution achieves the desired Manning Priority fill levels at each location. The second step distributes officers to all of the targets except for 346 (6 more) but requires only 1,373 or about 8% of the officer inventory to move. The number of moves filling open targets is 1,202. The additional 171 moves reduce overages by redistributing the excess officers. This

distribution has 6 more unfilled targets than the global model but cuts the number of moves by two-thirds.

1. Rank Substitution

If a location has an unfilled target for an assigned skill and rank, an excess officer one rank higher or lower with an eligible skill may serve as a rank substitute. We add the following constraint to DISTRIBUTOR that requires each location with an unfilled target to receive an excess officer one rank higher or lower or accounts for an inability to do so with an elastic variable, *RS*.

$$\sum_{c \in ELIG_{a,i}} OVER_{l,c,r+1,i} + \sum_{c \in ELIG_{a,i}} OVER_{l,c,r-1,i} \geq \sum_{i} UNDER_{l,a,r,i} - \sum_{i} RS_{l,a,r,i} \quad \forall l,a,r.$$

When the objective function penalty for the *RS* variables is less than the *UNDER* and *OVER* variables, the new distribution still has only 346 targets without an officer possessing the correct skill and rank. However, 188 of the 346 targets have an excess officer assigned as a rank substitute. The new distribution has 1,382 required moves and leaves 158 targets unfilled by an eligible officer or a rank substitute.

When the objective function penalty for the *RS* variables is greater than the *UNDER* and *OVER* variable penalties, the greatest penalty occurs in a location with an unfilled target with no available rank substitute. DISTRIBUTOR's results have 362 unfilled targets and require 1,405 moves. However, only 70 of the 362 unfilled targets do not have a rank substitute.

2. Fair Share

We add the following set of constraints to encourage an equitable distribution (fair share) of officers to generalist targets.

$$\sum_{l,r} ASSIGNED_{l,a,c,r} + \sum_{l,r} stepone_{l,a,c,r} \geq goal_{a,c} - \sum_{i} FS_{a,c,i} \quad \forall\ c, a \in ASGNc$$

These constraints ensure the total number of assigned officers from step one and step two for branch skill *c* filling the generalist assigned skill *a* are greater than that branch skills generalist goal or accounts for an inability to do so with an elastic variable, *FS*. We modify the objective function adding the elastic variable *FS* with a penalty. Table 10 displays the number of officers serving in generalist targets for the current

distribution, the fair share goal and the new distribution with the fair share constraints. The right columns display the number of officers below or over the goal number for the current distribution and the new distribution with the fair share constraints.

Branch	Current	Target	New	Current-Target	New-Target
11	573	680	608	-107	-72
13	411	426	392	-15	-34
14	200	211	210	-11	-1
15	449	582	584	-133	2
18	119	156	159	-37	3
19	365	424	411	-59	-13
21	218	174	215	44	41
25	194	198	230	-4	32
31	119	105	133	14	28
35	148	150	178	-2	28
42	110	106	136	4	30
44	31	54	66	-23	12
74	92	78	91	14	13
88	326	314	316	12	2
91	615	595	612	20	17
92	705	689	729	16	40

Table 10. Comparison of distributions with fair share targets. The number of branch officers serving in generalist targets in the current distribution, the fair share target and the new distribution. The columns on the far right display the difference of the fair share targets with the current distribution and the new distribution. The totals of the absolute values of the Current-Target and New-Target columns are 515 and 368 respectively.

Looking at Table 10, branch 15 has the most drastic change. In the current distribution, branch 15 is 133 officers short of filling its generalist billets but it is 2 over in the new distribution. Totaling the absolute values of the far right columns in Table 10 shows the new distribution more equitably distributes the generalist billets among the branches. The current distribution has a total of 515 officers over or under the generalist goal for each branch compared to 368 for the new distribution.

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V. CONCLUSION AND FUTURE RESEARCH

A. CONCLUSION

This thesis looked at distributing branch officers with the rank of Branch Qualified Captain to Colonel. Using data supplied by the Army, DISTRIBUTOR reduced the current distribution's 2,167 unfilled targets to 340 while requiring 4,688 or 28% of the officer inventory to move.

Implementing DISTRIBUTOR in the two sequential steps reduced the number of required moves. The first step optimally distributed the current inventory at each location and filled 619 unfilled targets. The second step used excess officers to fill targets at other locations. The new distribution had 346 targets unfilled but required only 1,373 or 8% of the officer inventory to move.

Adding a set of constraints to DISTRIBUTOR requiring rank substitution produced a distribution with 362 unfilled targets but only 70 of the unfilled targets did not have a rank substitute. Another set of constraints added to DISTRIBUTOR reduced the number of officers over or under the branch fair share goals from 515 officers to 368. This new distribution required 1,414 moves and had 362 unfilled targets. Only 70 of the unfilled targets did not have a rank substitute.

B. FUTURE RESEARCH

This thesis distributes branch officers. It may be possible modify DISTRIBUTOR to address other officer distribution problems such as functional area officers, joint officers, and special branches such as medical and chaplains.

The reduction of required moves can result in lower PCS costs. Moves could be further reduced by using excess officers to fill open targets at locations close to one another. For example, DISTRIBUTOR could be modified to have a preference to use excess officers from one brigade to fill open targets at other brigades located at the same post.

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LIST OF REFERENCES

Bausch, D. O., Brown, G. G., Hundley, D. R., Rapp, S. H., Rosenthal, R. E. , "Mobilizing Marine Corps Officers," *Interfaces*, v. 21, pp.26-38, July-August 1991.

Dzwonchyk, J.D., "An Improved Army Officer Distribution System", 72nd Military Operations Research Society Symposium, Monterey, California, 20 June 2004a.

Dzwonchyk, J.D., personal communication with Major J. D. Dzwonchyk, Operational Research/Systems Analyst, Distribution Development and Programs Branch, U. S. Army Human Resource Command, December 17, 2004b.

General Algebraic Modeling System 2005, www.gams.com, Retrieved August 21, 2005. GAMS Development Corp, 1217 Potomac Street, NW Washington DC 20007.

Hatch, B., personal communication with B. Hatch, Lecturer-Manpower Systems Analysis curriculum and Human Capital Researcher, Naval Postgraduate School, August 24, 2005.

House, J., personal communication with Major J. House, Operational Research/Systems Analyst, Distribution Development and Programs Branch, U. S. Army Human Resource Command, August 19, 2005.

Lianez, R., personal communication with Major R. Lianez, Manpower Systems Analyst, MMOA-5 Distribution, Manpower and Reserve Affairs, Headquarters Marine Corps, August 15, 2005.

Shrimpton, D., Newman, A., "The US Army Uses a Network Optimization Model to Designate Career Fields for Officers," *Interfaces*, v. 35, pp.230-237, May-June 2005.

Sweeny, J. B., *A Network Model (OSGM-NPS) For the U.S. Marine Corps Officer Staffing Goal Problem*, Masters Thesis, Department of Operations Research, Naval Postgraduate School, Monterey, California, September 1993.

Tivnan, B.F., *Optimizing United States Marine Corps Enlisted Assignments*, Masters Thesis, Department of Operations Research, Naval Postgraduate School, Monterey, California, September 1998.

Air Force Personnel Command, Military Assignments Officer, DPAO Ops Officer Assignments, Aircraft, Tactical Airlift courtesy [www.afpc.randolph.af.mil]. Retrieved September 2, 2005.

HRC, U. S. Army Human Resources Command, Officer Personnel Management, Operations and Plans Division courtesy [www.hrc.army.mil]. Retrieved August 21, 2005.

Xpress 2005, www.dashoptimization.com, Retrieved August 21, 2005. Dash Optimization Inc, 560 Sylvan Avenue, Englewood Cliffs NJ 07632.

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